EDI CON 2019

Electronic Design Innovation Conference

电子设计创新大会

April 1-3, 2019
China National Convention Center
Beijing, China

Exhibition Hours
April 1: 11:00-17:00
April 2: 9:30-17:00
April 3: 9:30-13:00

Antenna-in-Package Design: Where are my connectors? From Conducted to OTA

Markus Loerner, Market Segment Manager – RF & microwave component test

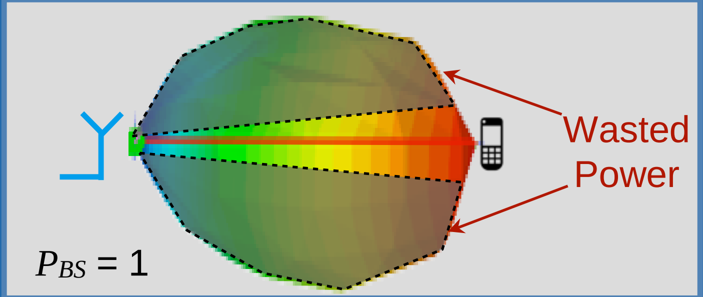
ROHDE&SCHWARZ

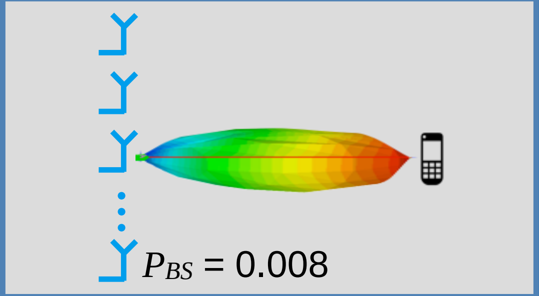
Industry trend

Platform trends

- 5G going pushes to beamforming
- Satellite payloads and ground stations for LEO systems
- EW systems starting for jamming and ESM
- Radars used phased arrays since the 60’s

Why beamforming with phased array?





	Number of Antennas = 1	Number of UEs: 1 120 antennas per UE
Number of BS Transmit Antennas	1	120
Normalized Output Power of Antennas	$P_{ant} = \frac{1}{M_t} = 1$	$P_{ant} = \frac{1}{M_t^2}$
Normalized Output Power of Base Station	$P_{total} = \sum_{i=1}^{M_t} P_{ant}^i = 1$	$P_{total} = \sum_{i=1}^{M_t} P_{ant}^i = 0.008$

Source: IEEE Signal Processing Magazine, Jan 2013

Easiest way to improve energy efficiency: more antennas

5G - frequency ranges

Frequency range	Range covered in Rel.15
FR1	450 MHz – 6000 MHz
FR2	24250 MHz – 52600 MHz

NEW: extension to 7.125 GHz
RAN #82 December 2018

- FR1: Evolution from LTE
- FR2: All different
  - Higher complexity in device development
  - Measurement challenges
  - New testing approaches

- Separate specs for FR1 and FR2

New NR bands in FR2

5G
mmW

Band number	UL	DL	Bandwidth	Duplex mode
n257	26.5 – 29.5 GHz	26.5 – 29.5 GHz	**3000 MHz**	TDD
n258	24.25 – 27.5 GHz	24.25 – 27.5 GHz	**3250 MHz**	TDD
n260	37 – 40 GHz	37 – 40 GHz	**3000 MHz**	TDD
n261	27.5 – 28.35 GHz	27.5 – 28.35 GHz	850 MHz	TDD

- mmWave only TDD
- Reciprocal channel
- Good for beamforming

38.521-2 V15.1.0

mmWave aspects

- Why mmWave?

$$C = \boxed{B} * \log_2(1 + \frac{S}{N})$$

  - High data rate requires high bandwidth
  - High contiguous bandwidth is rare in lower frequencies

BUT:

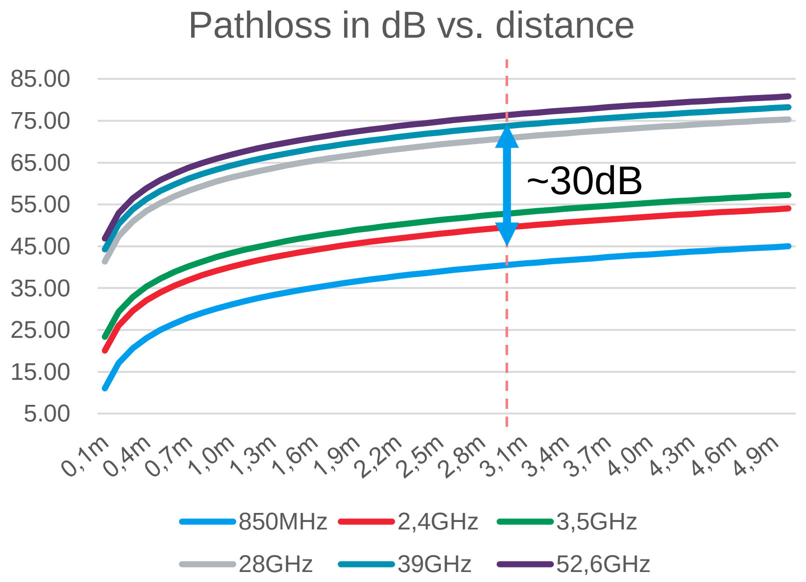
  - High frequencies – high free space path loss

$$\mathrm{FSPL} = 20\log_{10}(d) + 20\log_{10}(f) + 20\log_{10}\left(\frac{4\pi}{c}\right)$$

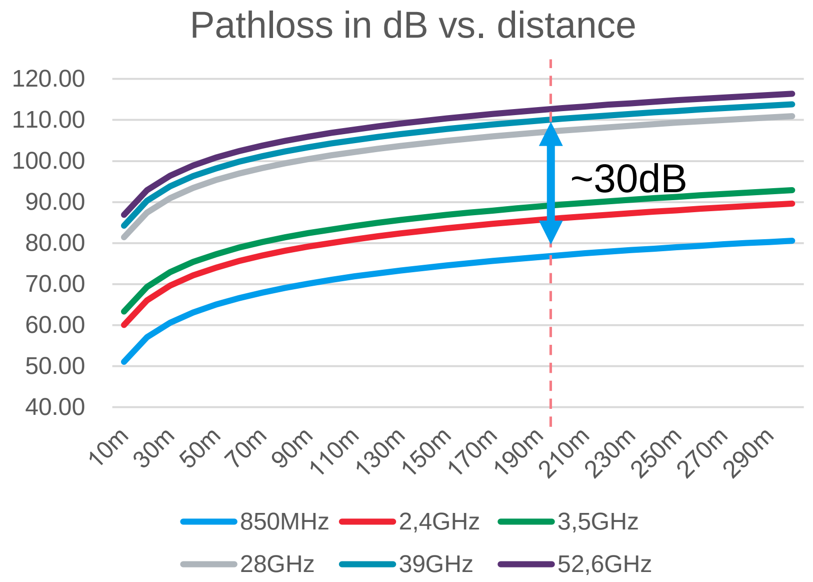
  - LOS (line of sight) requirements

30dB more free space pathloss in mmWave

Chambers

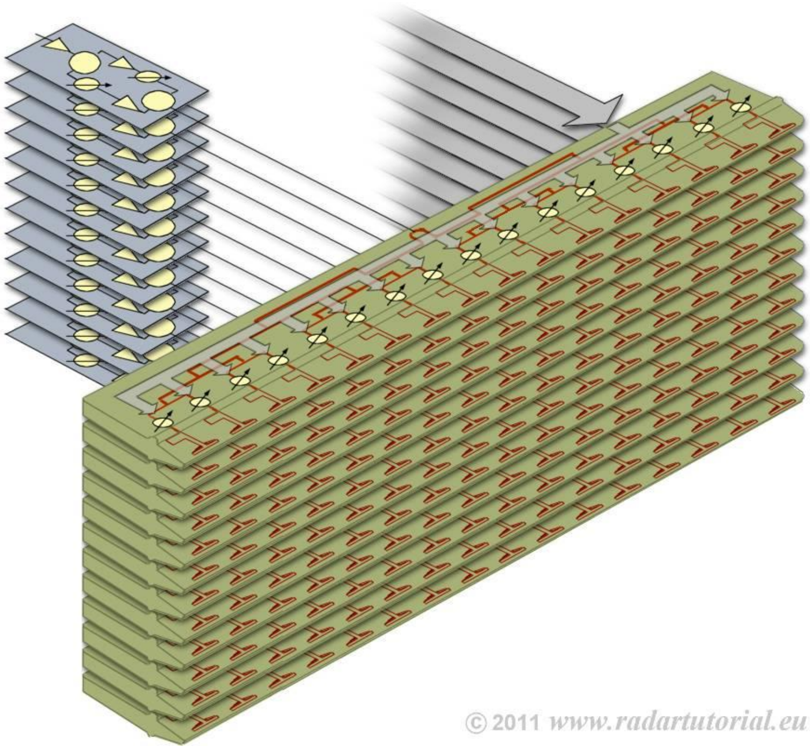


Small cells



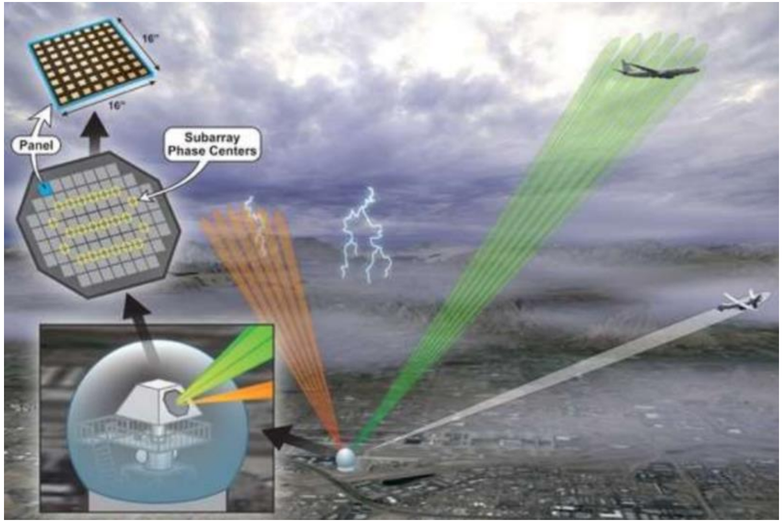
Phased Arrays – not a new concept

- Common concept



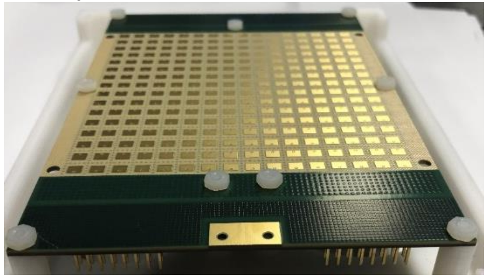
Phased Arrays – moving forward

- Now planar using much higher integration

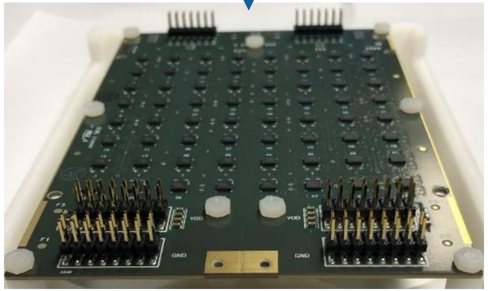


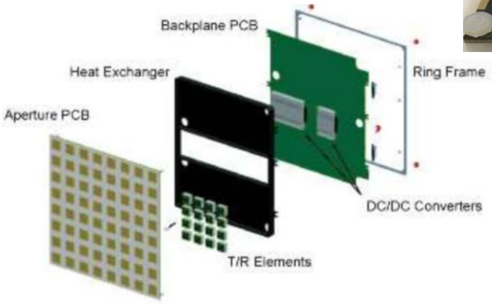
Courtesy of IDT.com

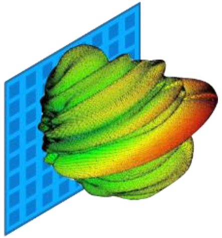
Front



Back







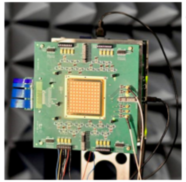
Next steps

- Integration of antenna in package
- Mainly driven by 5G, 60 GHz and automotive radar
- Antenna on chip is possible for higher frequencies, 100 GHz and above

- How to test these devices?

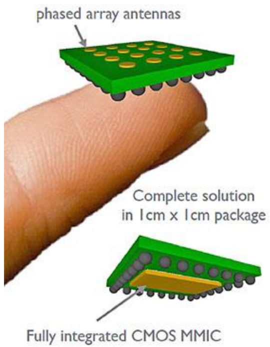
IBM and Ericsson Announce 5G mmWave Phased Array Antenna Module

February 7, 2017 IBM and Ericsson No Comments



At the International Solid-State Circuits Conference (ISSCC), **IBM** and **Ericsson** announced what they claim is the world's first reported Si millimeter wave phased array antenna module operating at 28 GHz. The module is the result of a two-year collaboration between IBM Research and Ericsson, intended to develop technology for 5G infrastructure.

The module consists of four MMICs and 64 dual-polarized antennas and measures approximately 2.8" x 2.8" — about half the size of a typical smartphone. The module and MMICs are designed for concurrent dual polarization operation in transmit and receive. This enables one phased array antenna module to form two beams simultaneously, doubling the number of users that can be served. The phased array design supports beam-steering resolution of less than 1.4 degrees.



https://www.electronicproducts.com

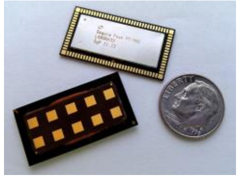
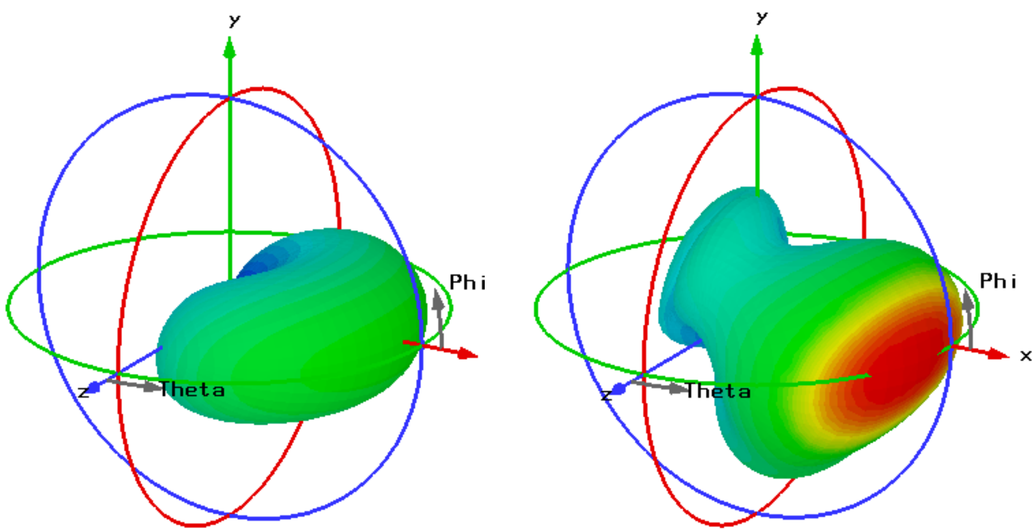


Photo: Baljit Singh/Intel Corporation

It’s all about no cables …

3D gain patterns of mmWave UE antenna

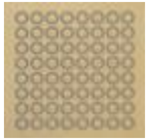


No measurement cable

With measurement cable

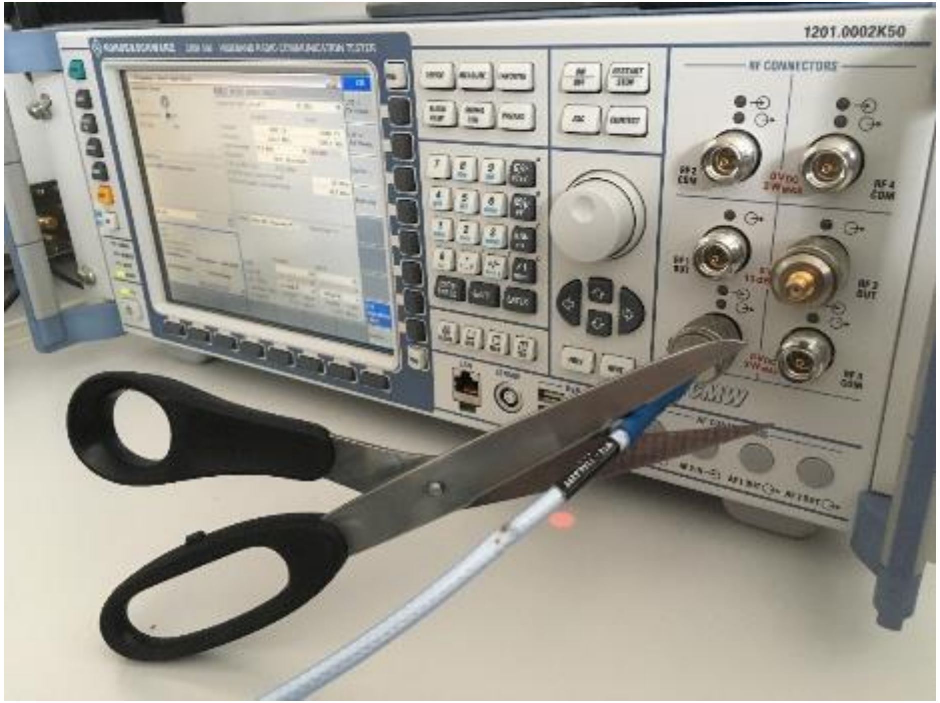
Antenna couples to all surrounding objects
Conductive measurements introduce large error

- Phased arrays do not allow connection through cables



  - Many antennas – many connectors
  - Cable influences antenna characteristics
  - Antenna becomes system relevant functionality with beamforming etc.

Testing of mmWave devices – Just removing cables?



Why OTA testing?
In 5G: 3GPP TR 38.803 NR RF testability

Conducted testing

Re-use LTE UE
testing methodology

6 GHz

24 GHz

OTA measurements

in far field*

*Note: Alternative near field methods are not precluded

Only antenna performance tested requires over the air (OTA) [TRP, TIS, …]

Everything to be tested over the air (OTA)

Source: 3GPP TR 38.803 V2.0.0

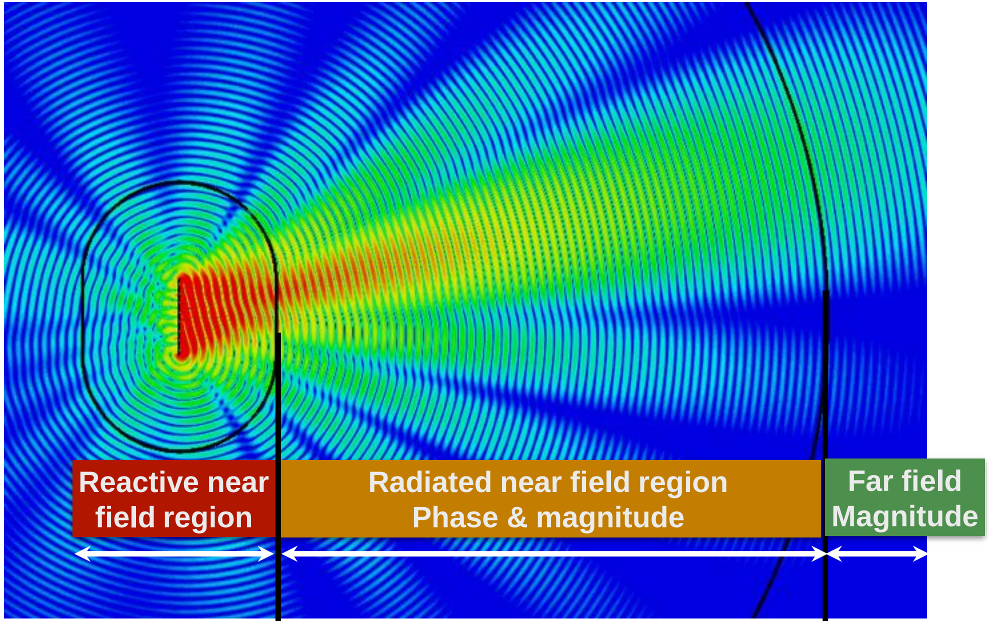
New challenges coming up with OTA testing

- Testing in OTA is not new
- But now all performance data needs to be test OTA in mmWave!

- Lots of new things to consider
  - Radiation pattern of the antenna
  - Field properties of the radiation
  - Near field vs. far field conditions
  - Quiet zone sizes
  - Chamber sizes
  - Positioners
  - …

Fundamental properties: electromagnetic fields

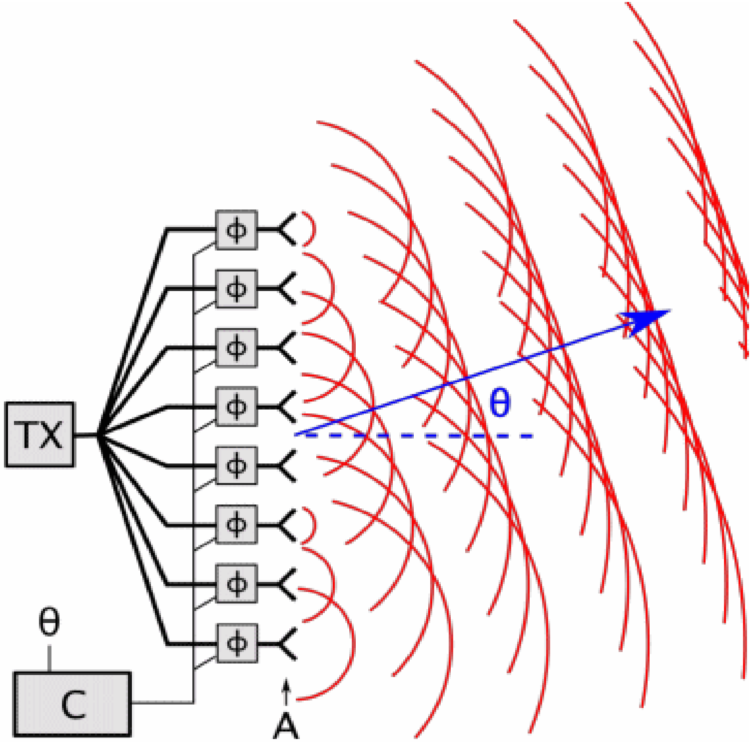
0.1 m aperture size at 28 GHz



$$0.62\sqrt{\frac{D^3}{\lambda}} \overset{*}{=} 19\ cm$$

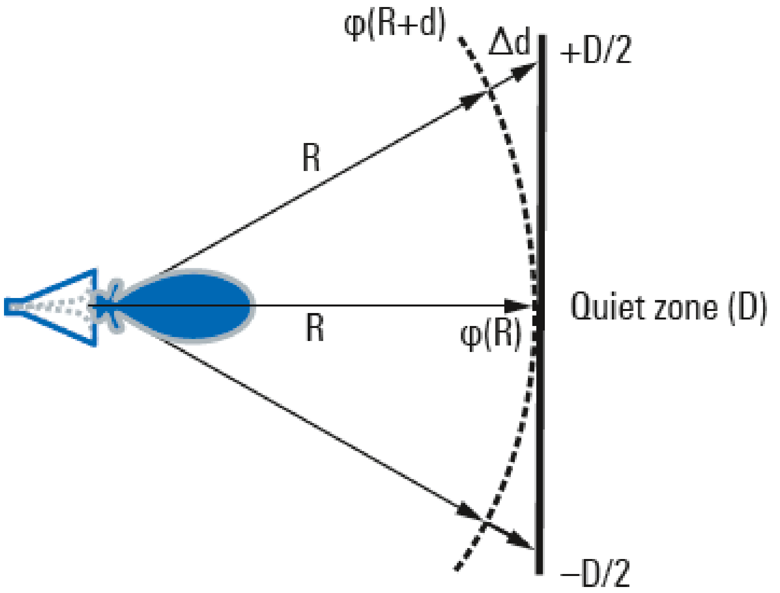
$$\frac{2D^2}{\lambda} = 1.87\ m$$

* = formula commonly taken for radiators with D>$\frac{\lambda}{2}$



What is the quiet zone?

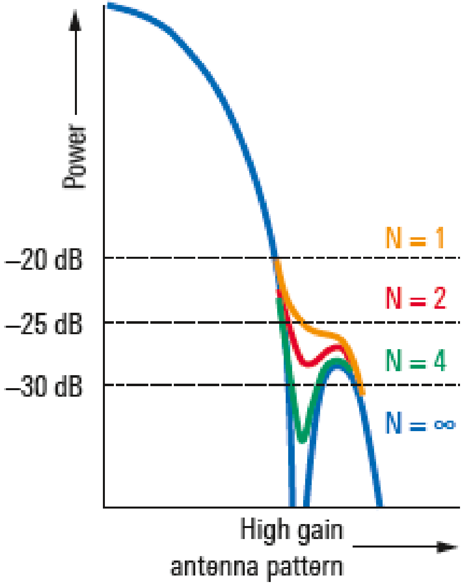
Definition of Fraunhofer distance



Quiet zone phase deviation and magnitude error

$$R_{FFmin} = \frac{ND^2}{\lambda}$$

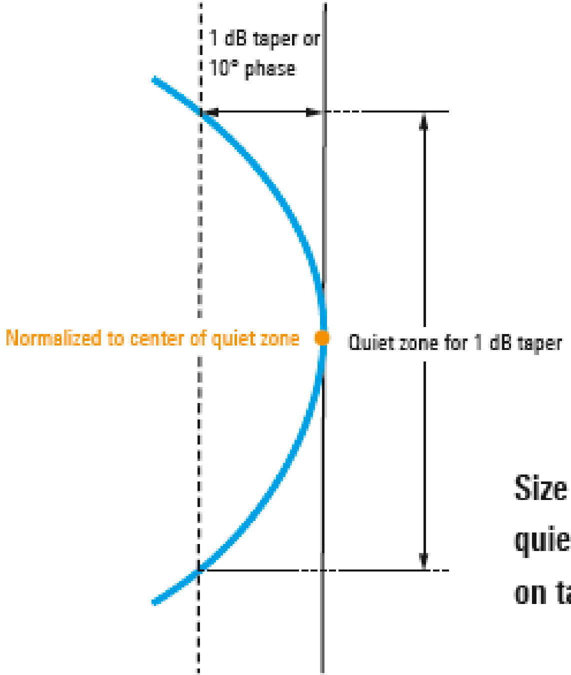
R_{FFmin} (N)	Phase deviation (φ)
D^2/λ	45°
$2D^2/\lambda$	22.5°
$4D^2/\lambda$	11.2°
$8D^2/\lambda$	5.6°



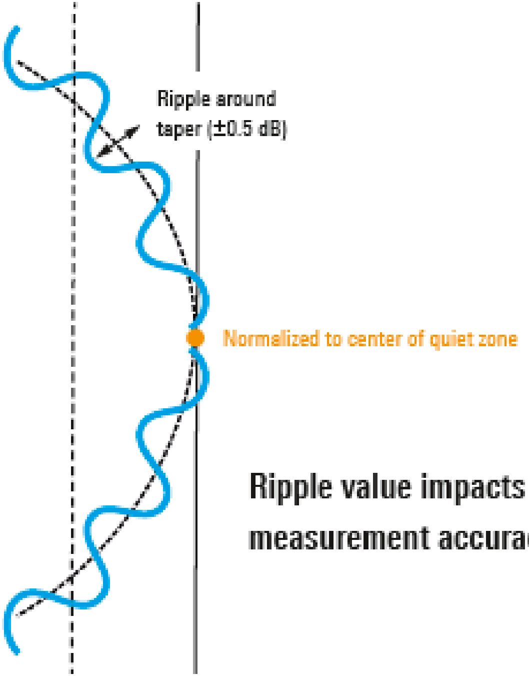
The Fraunhofer distance presents the best compromise between a compact test setup, acceptable phase deviation and measurable null

How good is the quiet zone?

Example of amplitude/phase taper	Example of amplitude/phase ripple



Size of achievable quiet zone depends on taper value.



Ripple value impacts measurement accuracy.

What size of a quiet zone (QZ) is needed?

D = size of radiating aperture
λ = wavelength

- Small building block
  - This size can be taken as D

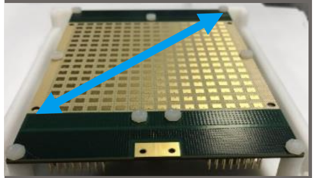
e.g. QZ size 3 cm; 30 GHz → λ = 1cm ; $\frac{2D^2}{\lambda}$ far field distance 18 cm

- Complete subsystem
  - Entire DUT maximum distance to be considered as D

e.g. QZ size 28 cm; 30 GHz → λ = 1 cm; $\frac{2D^2}{\lambda}$ far field distance 16 m

D= ~3 cm

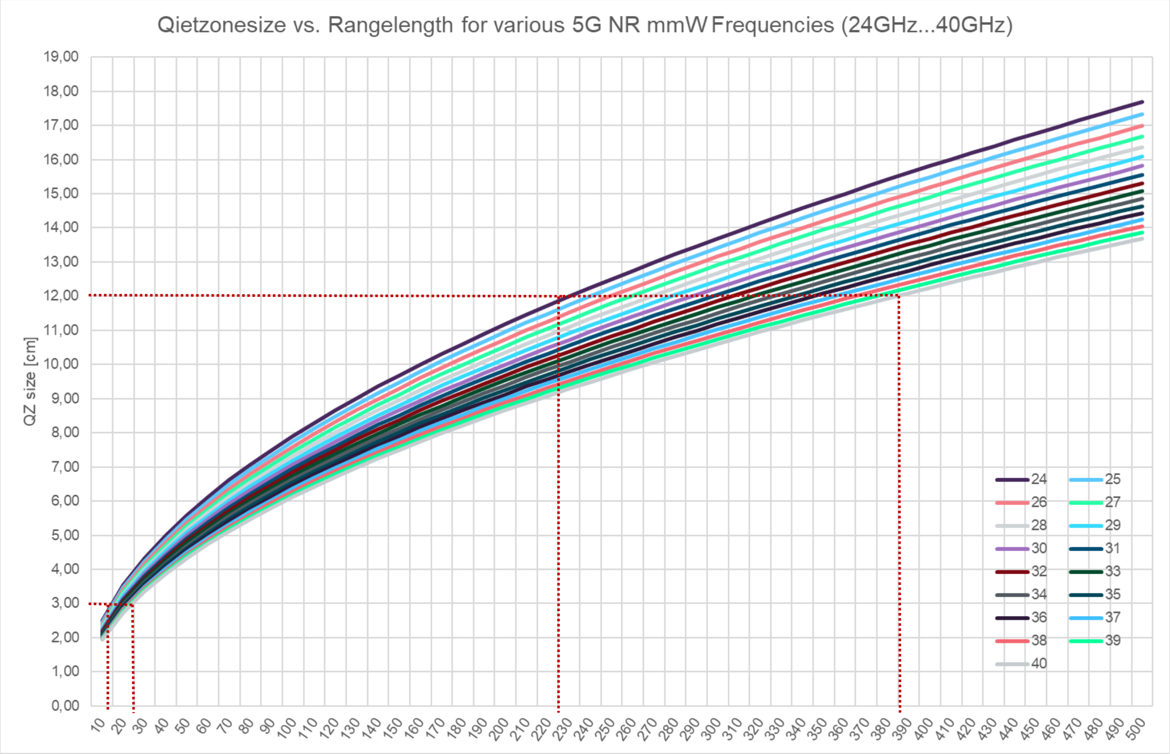
D= ~28 cm



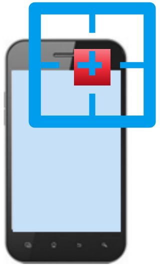
How big of a chamber is required for direct far field?

- Quiet zone size (black box)

- Chamber size 3 m…5 m

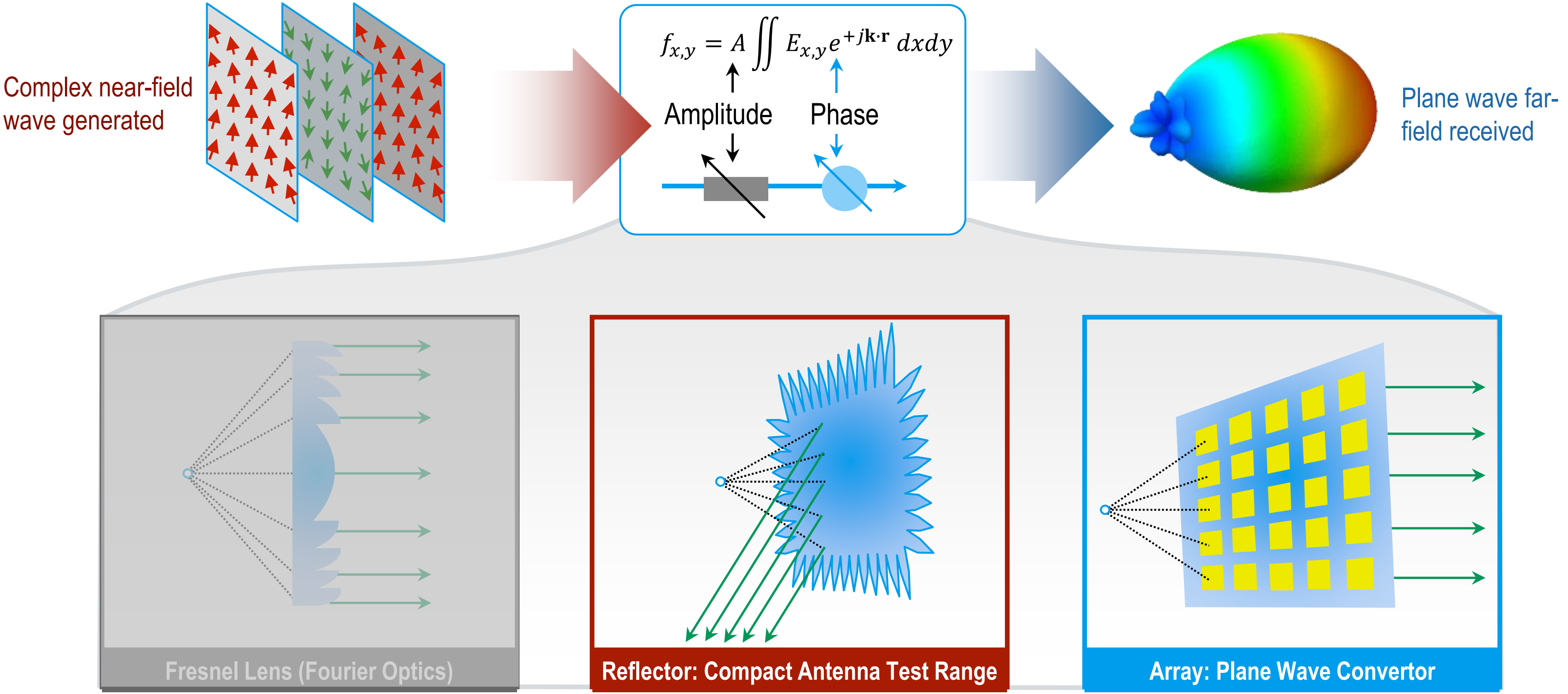


- Quiet zone size (white box)

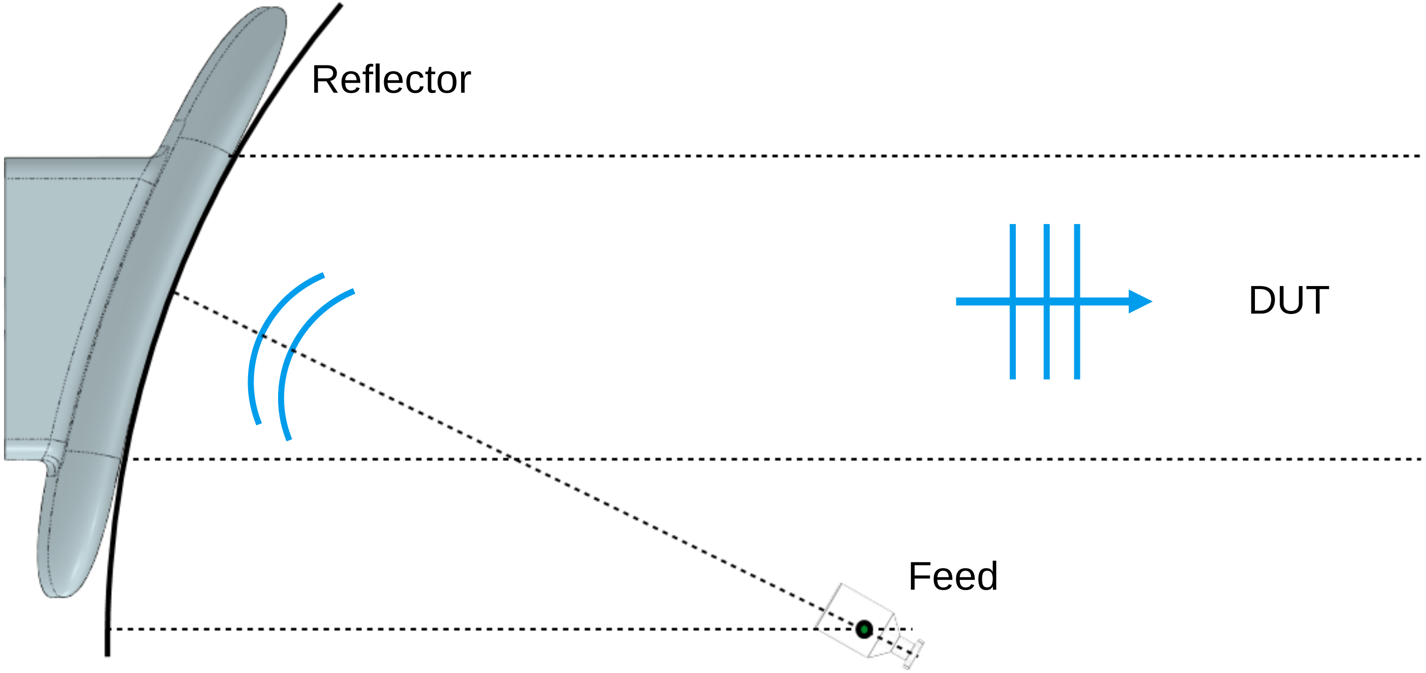


- Chamber size 0.5 m

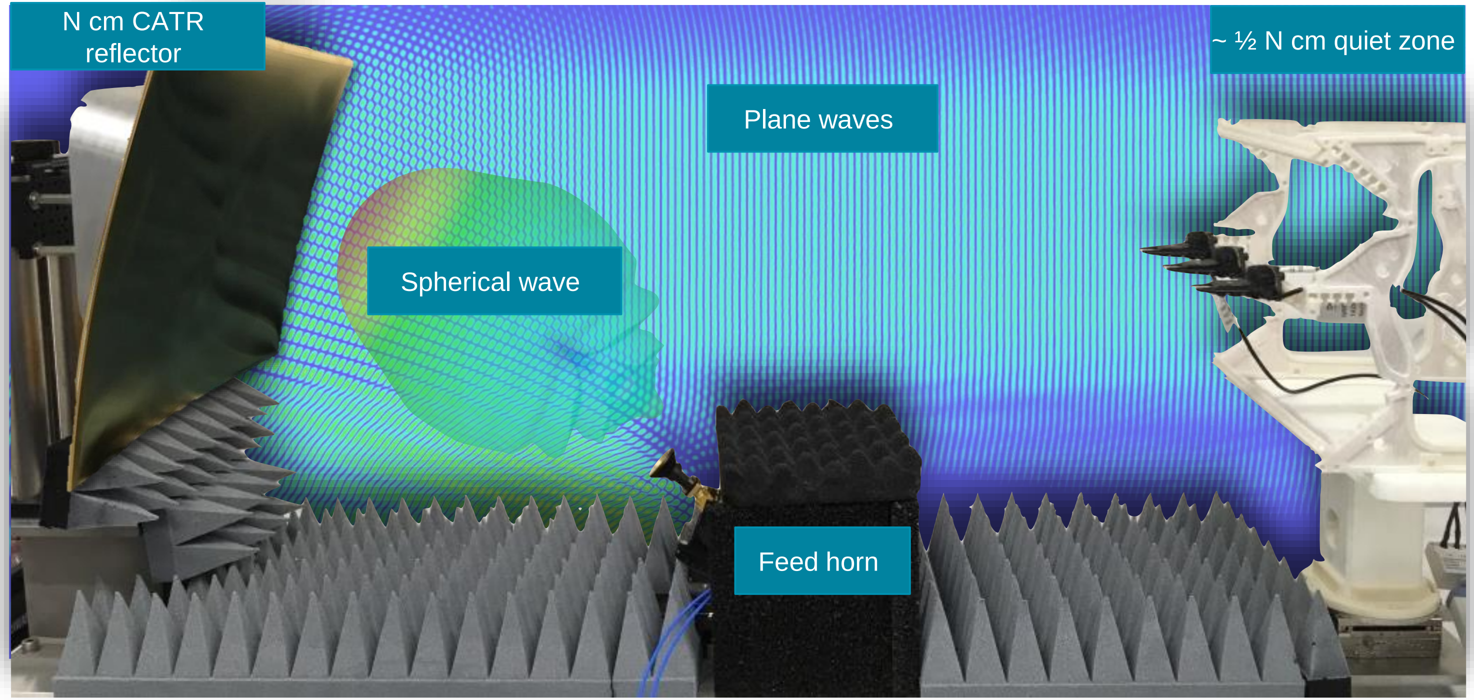
Far-field to near-field systems: hardware Fourier transforms



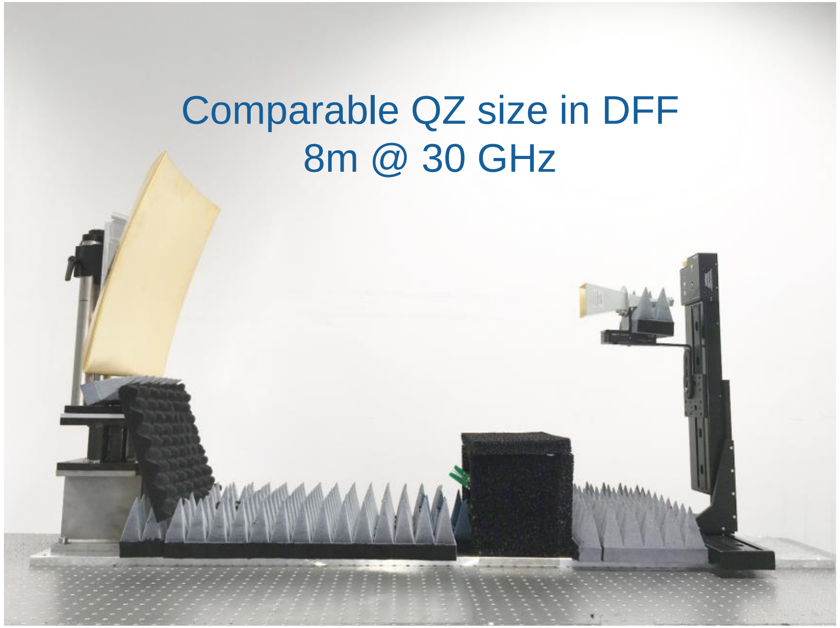
Possibilities to shrink the chamber size – indirect far field



CATR – Compact Antenna Test Range

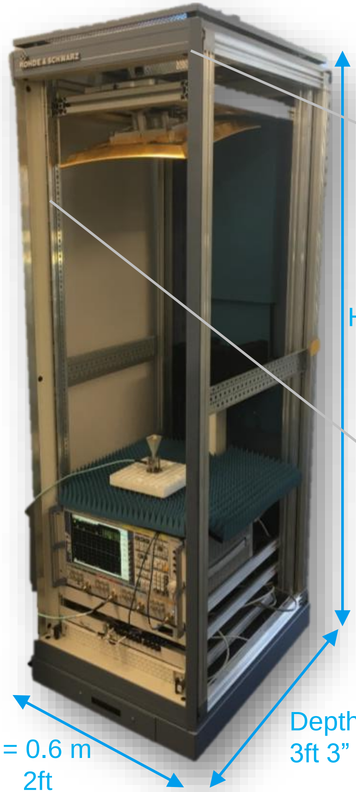


ATS800B – large quiet zone for R&D and pre-conformance



- High-accuracy 42 cm reflector
- Broadband dual-polarized feed
- 20 cm quiet zone (QZ)
- Size approx. 0.4 m x 0.8 m x 1.2 m
- Frequency range FR2
- Cost-effective, small footprint and versatile solution for
  - R&D testing
  - protocol testing

ATS800R – rack-integrateable version

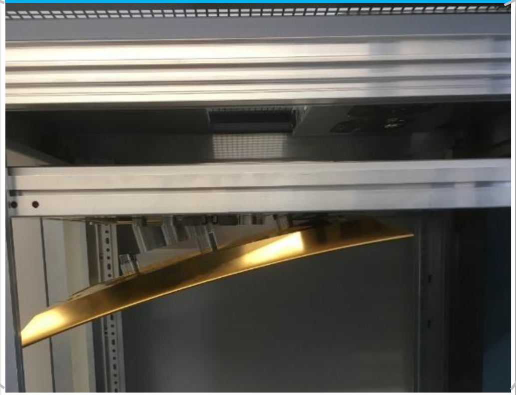


Height = 2 m
6ft 6”

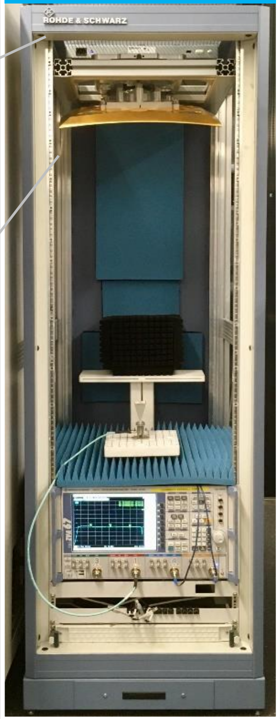
Depth = 1 m
3ft 3”

Width = 0.6 m
2ft

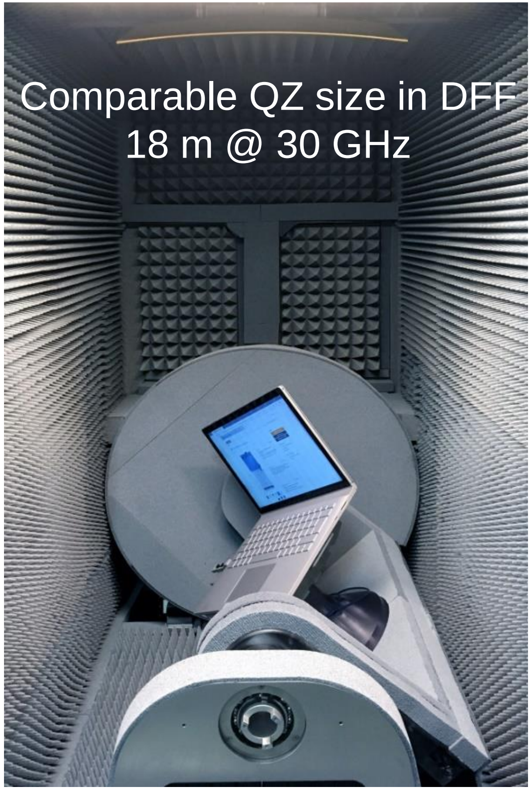
Reflector rack mounting
Adjustable tilts in 2 planes



Front view



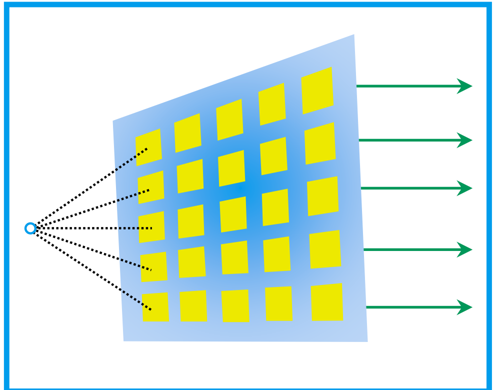
ATS1800C - full conformance / compliance testing solution



- High-accuracy 52 cm reflector
- Broadband dual-polarized feed
- 30 cm quiet zone (QZ)
- Chamber size approx. 1 m x 1.5 m x 2 m
- Frequency range FR2
- All-in-one conformance / compliance test solution for
  - 3GPP FR2 RFCT
  - 3GPP FR2 PCT
  - CTIA FR2 compliance

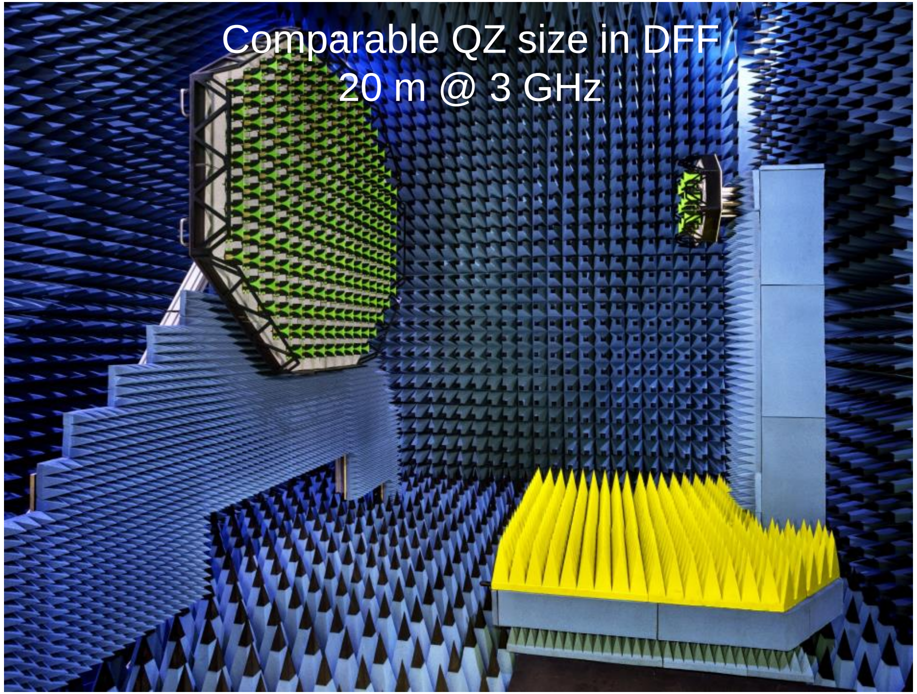
The plane-wave synthesis approach – advantages sub 6 GHz

- Weight, size and cost of CATR reflectors high for large devices (NodeB) in FR1
- Plane-wave synthesis lightweight and compact alternative using phased antenna array
- For a quiet zone of size D
  - CATR system distance between reflector and DUT is 3 to 4 D
  - Plane-wave synthesis system 1.5 to 2 D


Array: Plane Wave Convertor

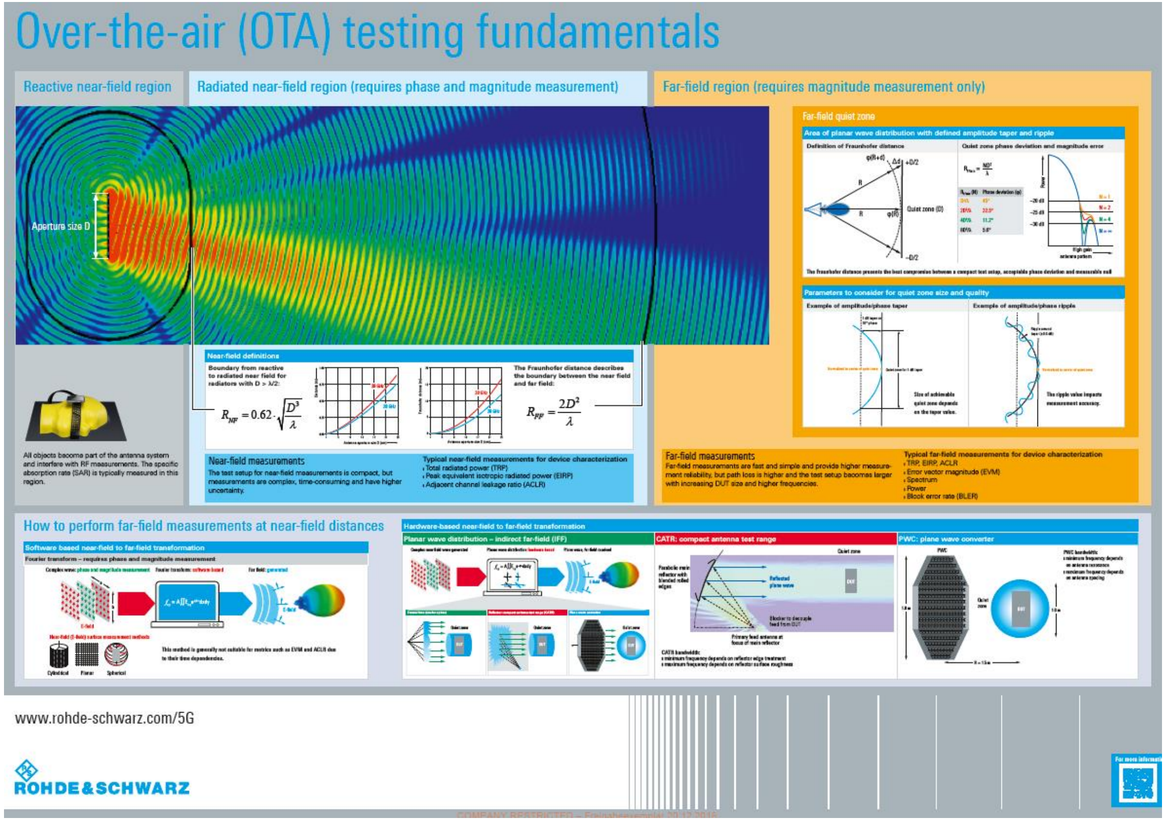
Plane-wave synthesis system realization

- One RF port
- Signal distributes to 156 Vivaldi antennas through phase shifters and attenuators
- The fields generated by the antennas combine in the target region to generate a plane-wave front (reciprocal device)
- 1 m spherical quiet zone (QZ) at 1.5 m distance
- Frequency range FR1



R&S®PWC200 Plane Wave Converter

OTA testing fundamentals poster



Download at

www.rohde-schwarz.com/OTA-poster